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Next Generation 2.75-Inch Rocket Propulsion

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OVERVIEW

- Some definitions
- Causes of early flight errors
- How the Mk 66 reduces errors
- How the NGR works
- Future prospects

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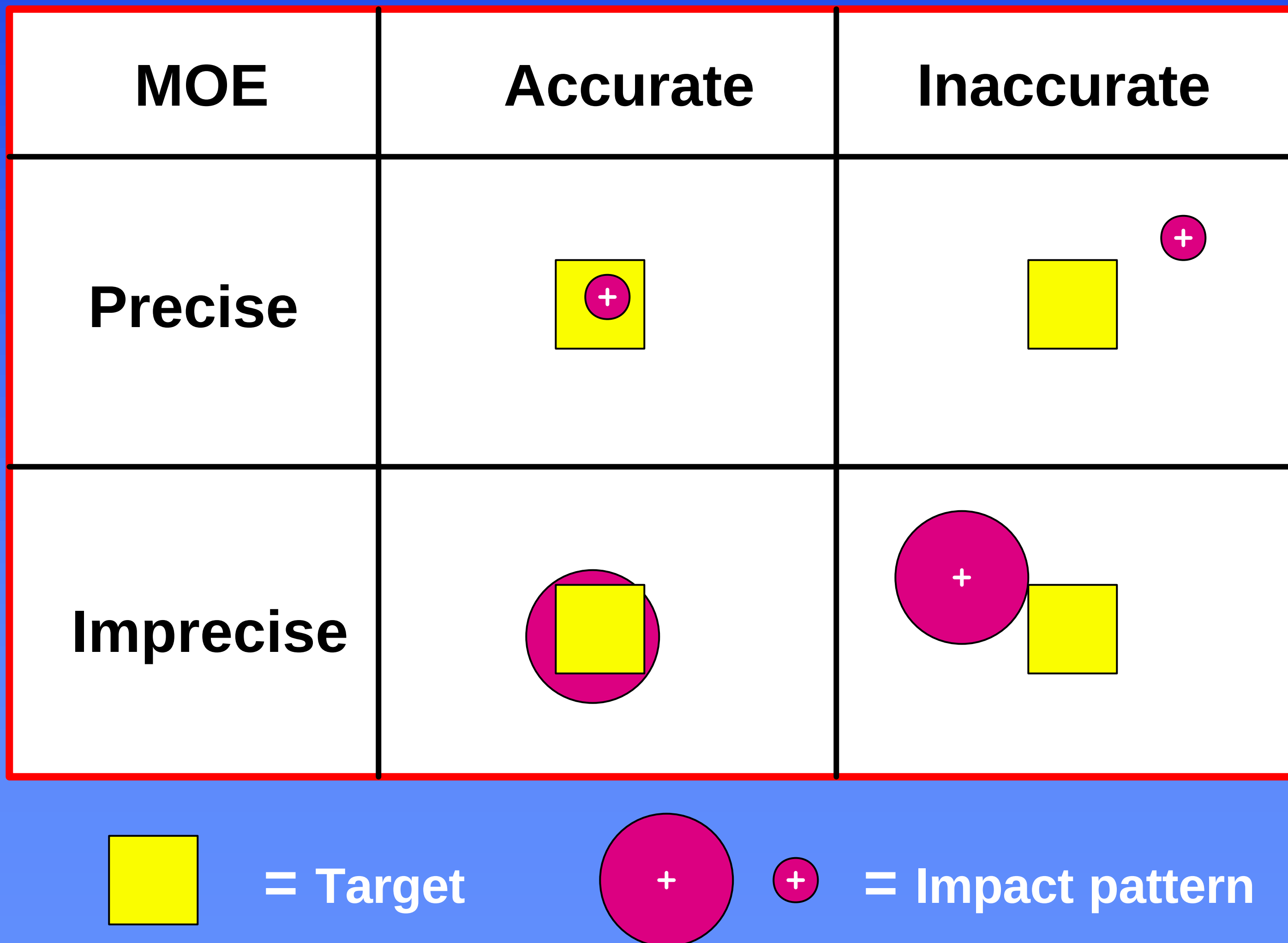
Precision and accuracy are separate measures of performance



Guided missiles and rockets differ in their ability to correct for errors

“Typical” Missile	2.75-Inch Rocket
Rocket Motor •Provides forward thrust Guidance & Control •Implements action to correct for perceived deviations	Rocket Motor •Provides forward thrust +Provides aero stability +Provides spin profile Guidance & Control •NONE
Errors are nullified throughout flight	Errors accumulate throughout flight

Thrust misalignment is the principal cause of dispersion

"... thrust asymmetry is the dominant factor causing dispersion of finned field rockets."

F.R. Gantmakher and L.M. Levin

<u>The Flight of Uncontrolled Rockets</u>

translation of 1964

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Precision improvement impetus has led to a number of related design initiatives

- Reduce Target Miss Distance
  - Reduce Rocket Variability
    - Reduce Thrust Misalignment
      - Tighten Tolerances
      - Improve Nozzle Alignment
      - Increase Exit Spin
        - Increase Torque
        - Decrease MOI
  - Reduce Effect of Launch Perturbations
    - Lessen Sensitivity

The value of spin has long been recognized

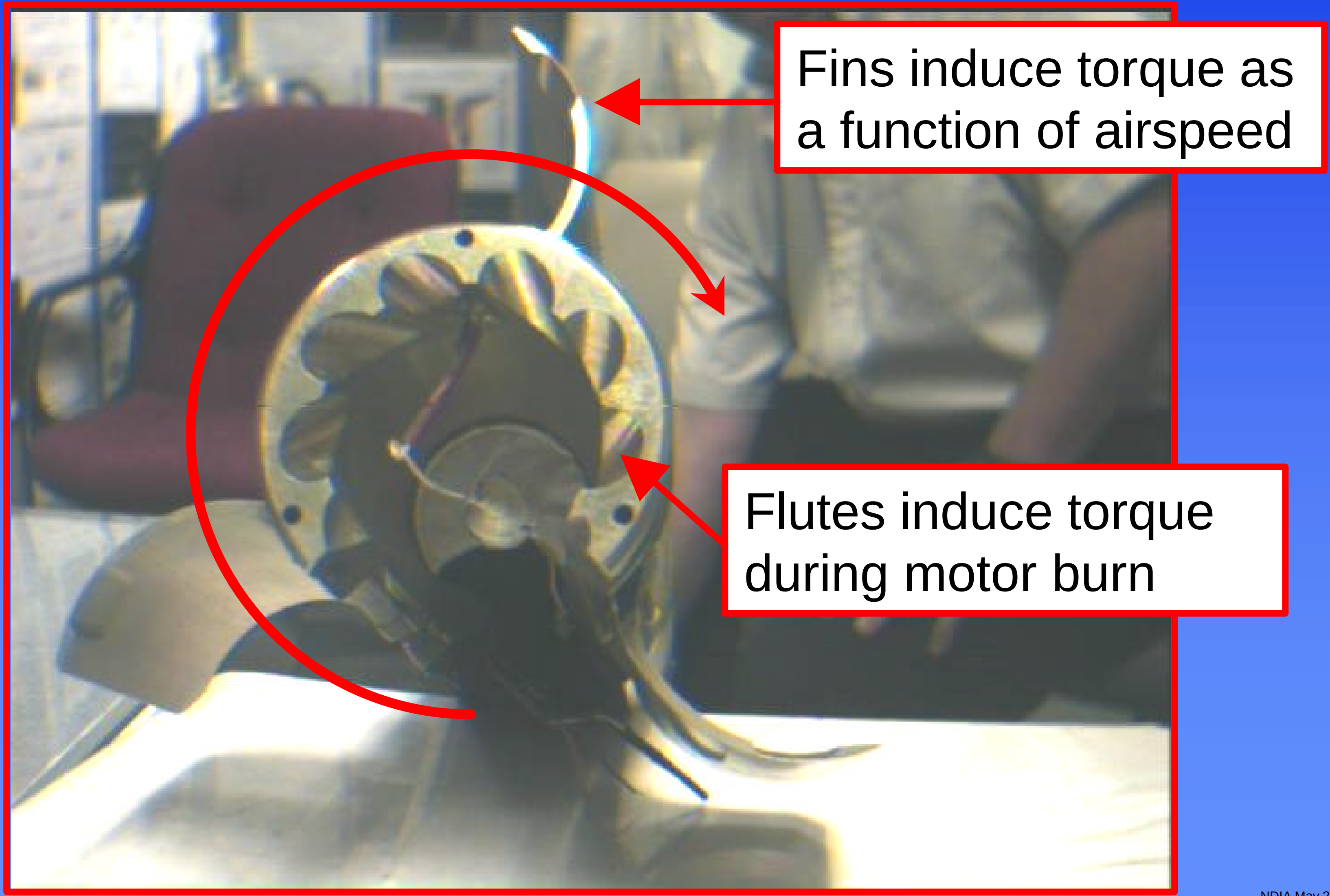
"Ever since rockets have been in use, attempts have been made to increase their accuracy in flight by imparting rotational motion to them about the longitudinal axis."

K.I. Konstantinov

Military Rockets

1856

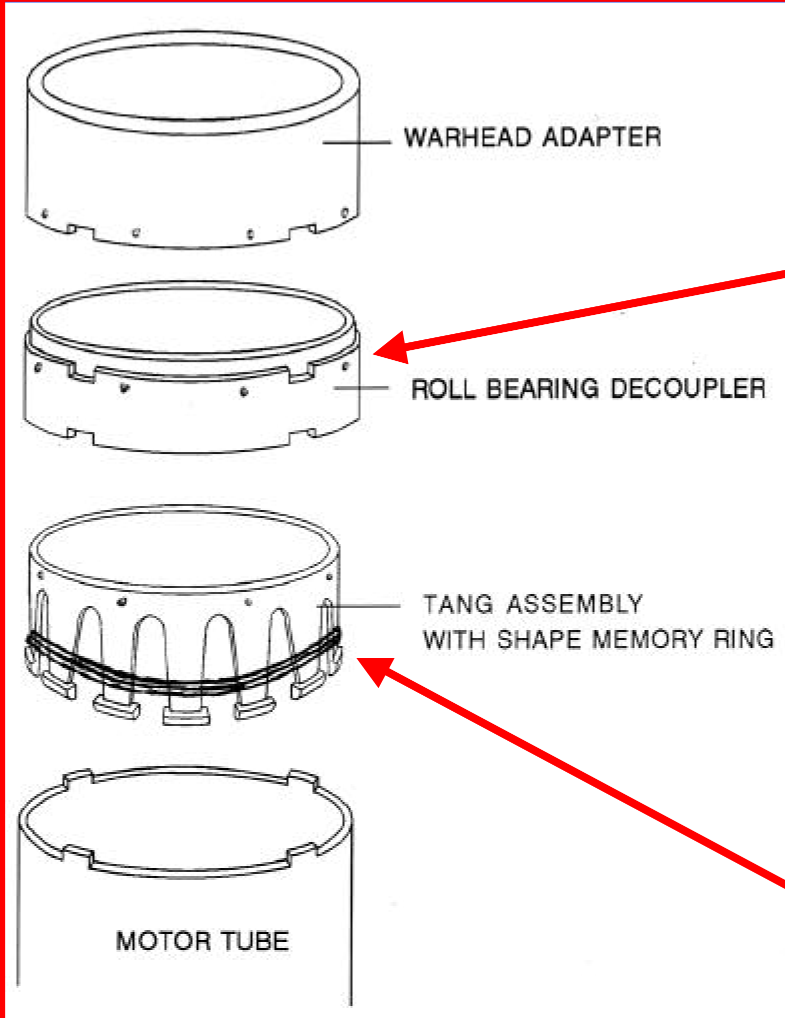
Mk 66 motor achieves spin through two mechanisms



Next generation motor has modified functionality

Current Mk 66	Improved Precision Mk 66
•Provides forward thrust •Applies roll torque throughout motor burn •Applies torque to motor and warhead •Provides large aerodynamic restoring moment for stability	•Provides forward thrust •Applies roll torque in launcher tube •Applies torque to motor only •Provides small aerodynamic restoring moment for stability

Roll bearing allows motor to spin with minimal warhead spin



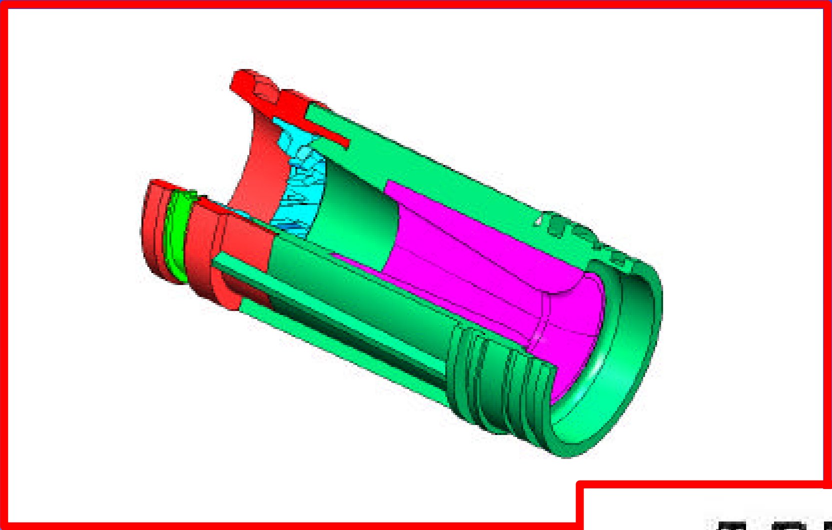
WARHEAD DECOUPLER :
- Increases rocket motor spin rate at launcher tube exit
- Reduces risk of over-spinning warhead fuze.
- Allows guidance in future warhead designs.

Roll bearing being developed in conjunction with AMRDEC, Huntsville

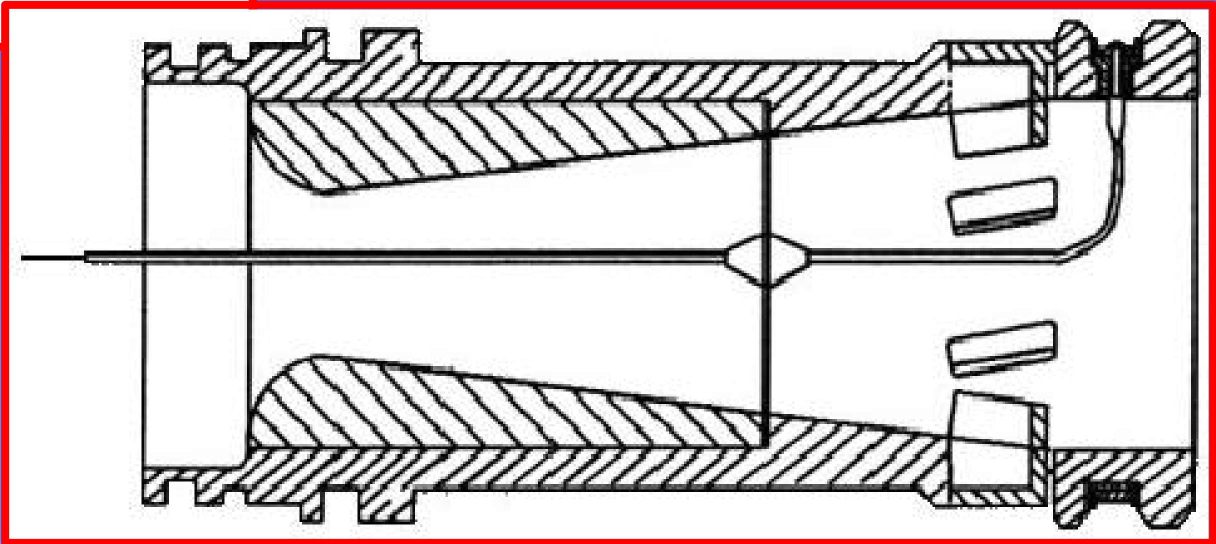
RELEASE COUPLER:

- Allows graceful failure of forward bulkhead (Insensitive Munitions Initiative)

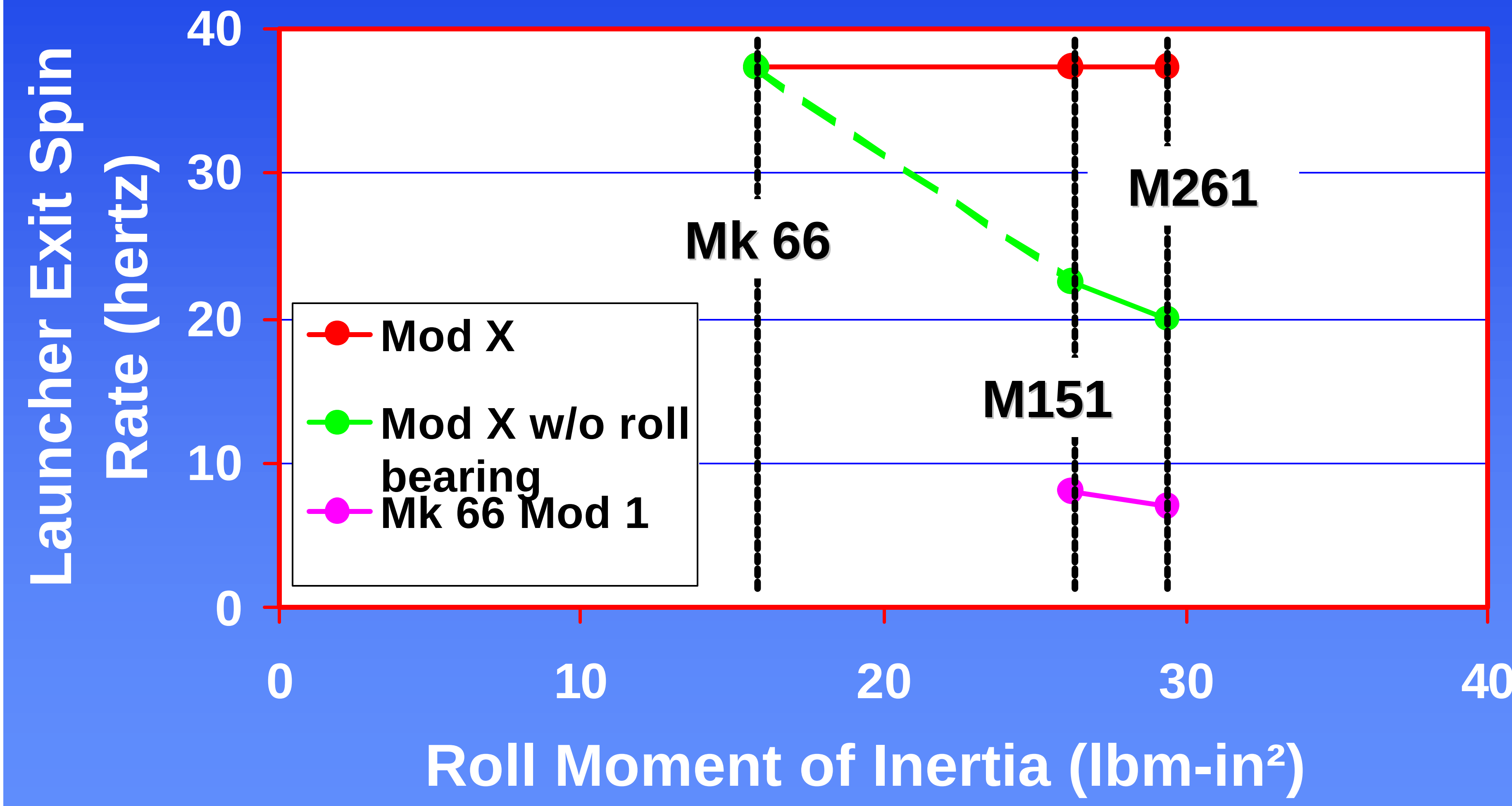
Eroding vanes deliver requisite torque in launcher tube



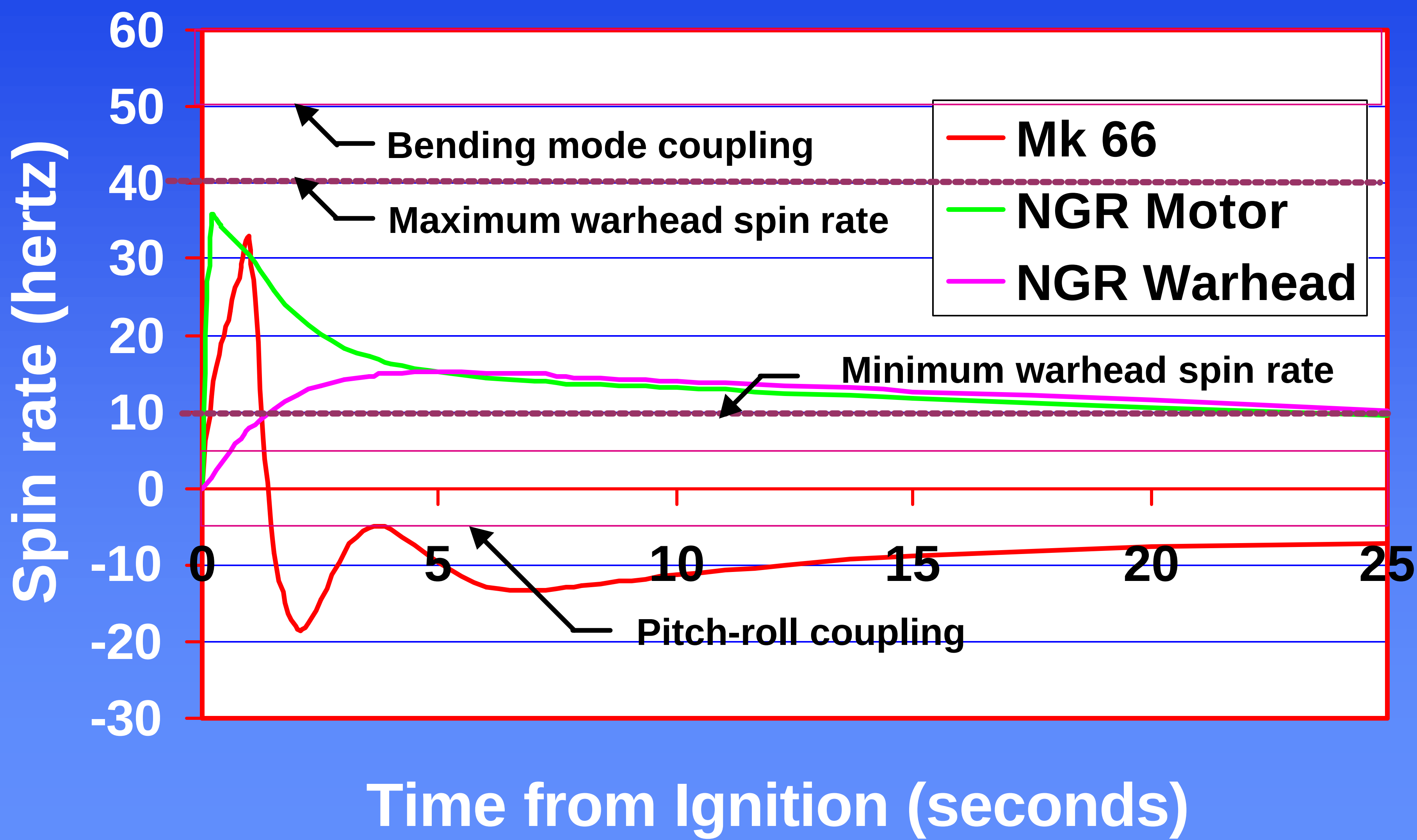
Through a joint effort with General Dynamics, polymers have been identified to provide torque-vs.-time profile of 10 ft-lbf for 0.080 seconds.



Combination of vanes & roll bearing yields constant performance



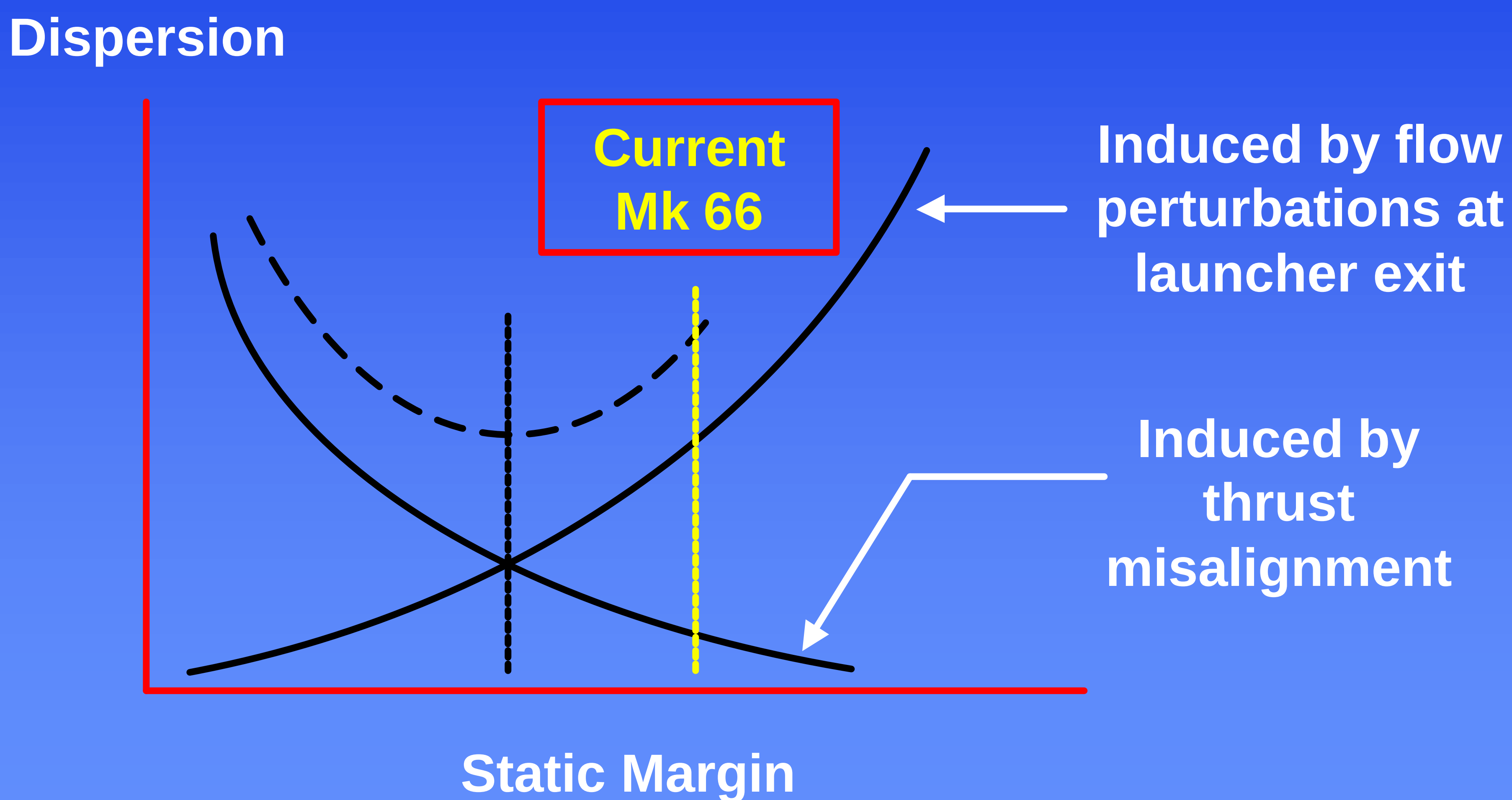
Spin rate will be tailored to comply with system requirements



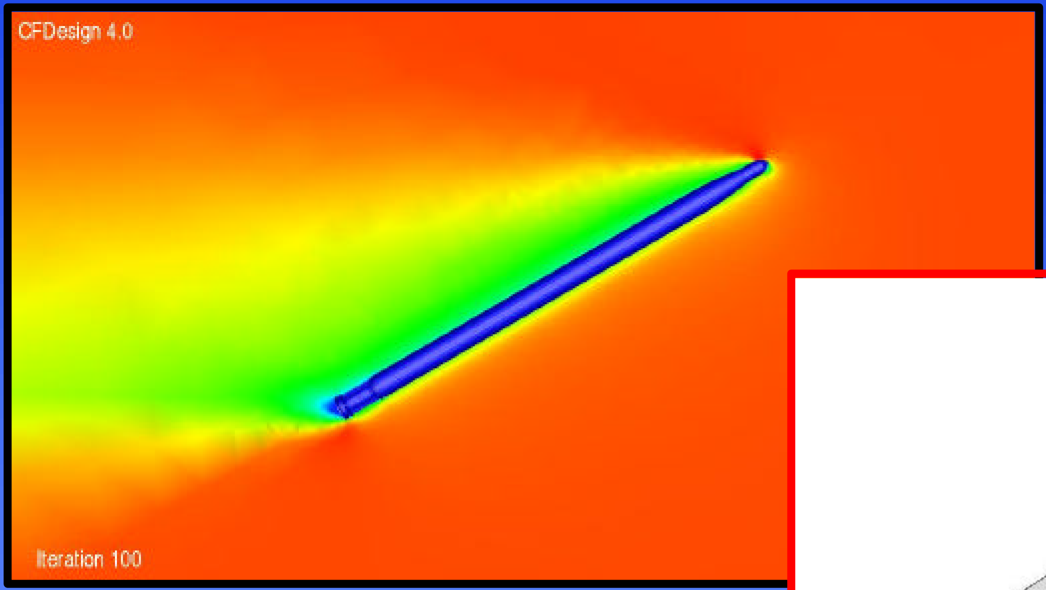
To improve precision, errors at launch need to be reduced

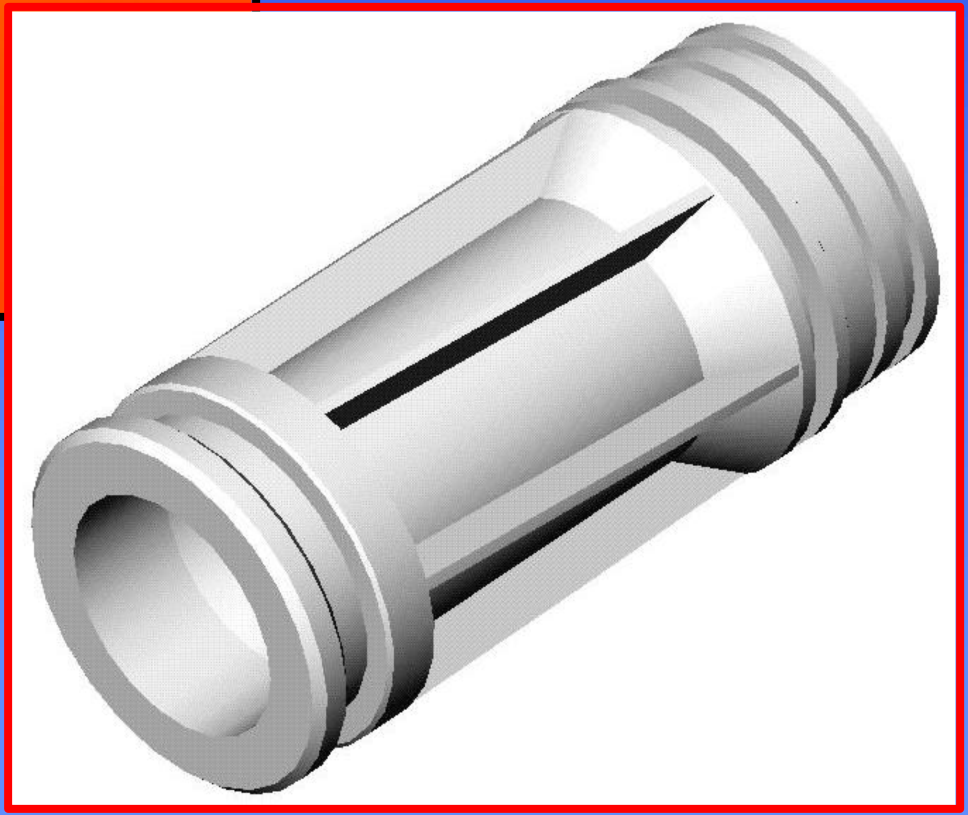
- Under helo's rotor blades, rocket encounters spatial and temporal variations of the "local wind"
- Helicopter launch environment is dynamic and chaotic
- Perturbations during the launch process are the equivalent of aiming errors
- Reducing launch errors implies making the rocket less responsive to its environment

A rocket can be “too stable”



Computational Fluid Dynamics led to a radical design





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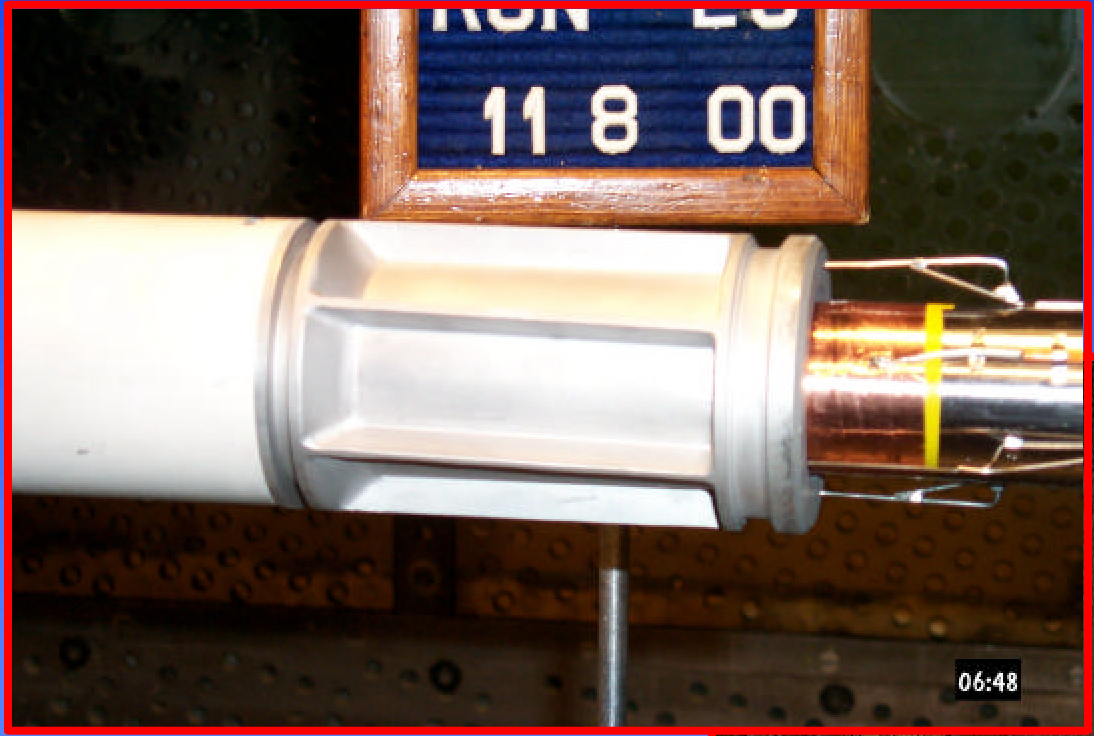
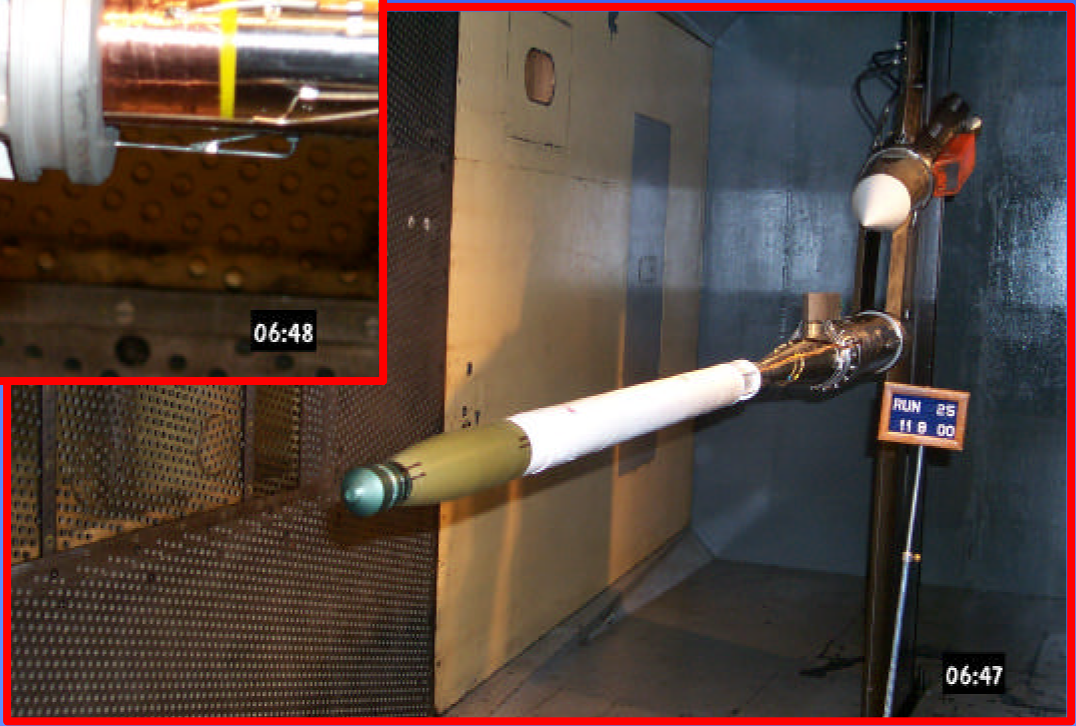
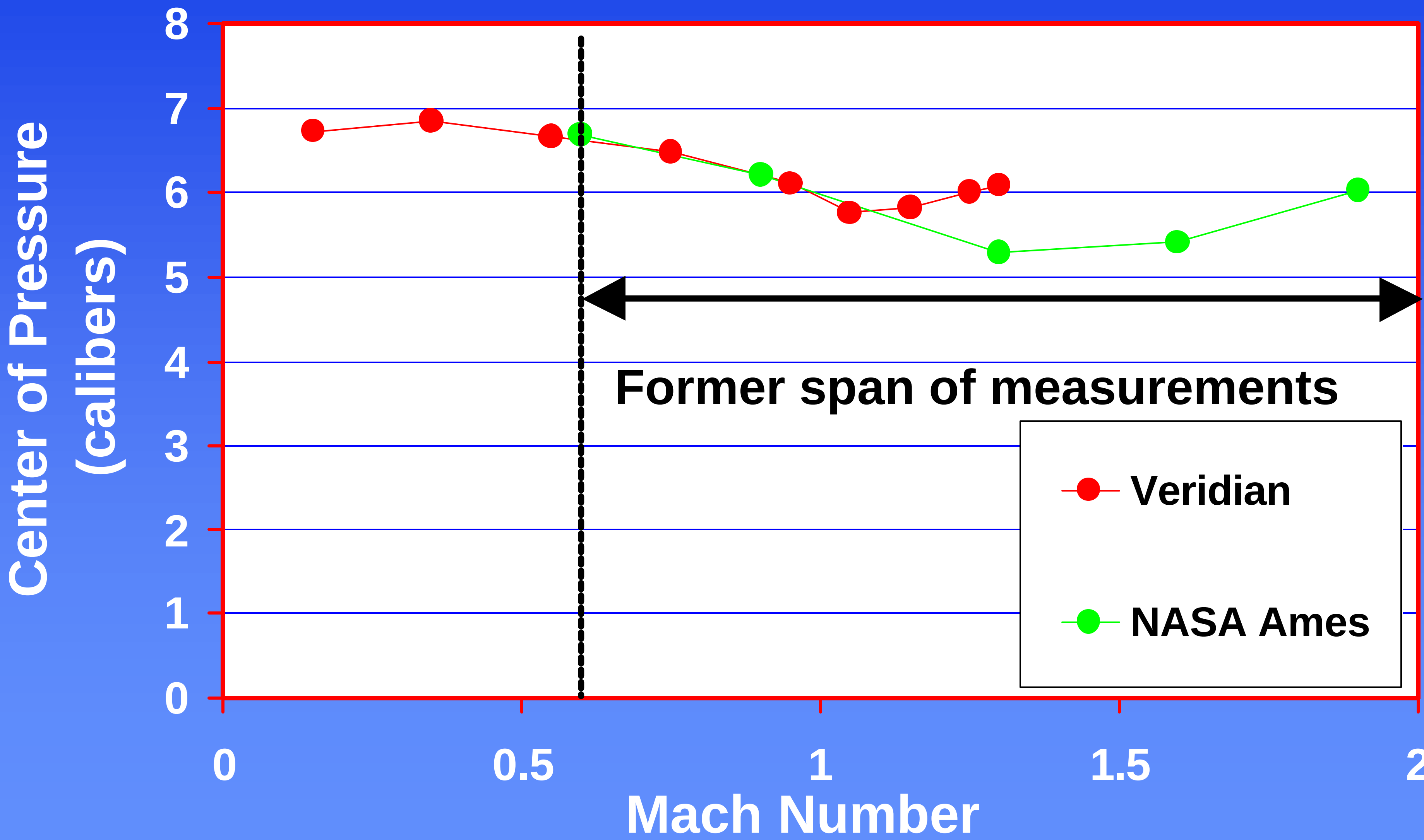
Wind tunnel tests were conducted from Mach 0.15 to Mach 1.3

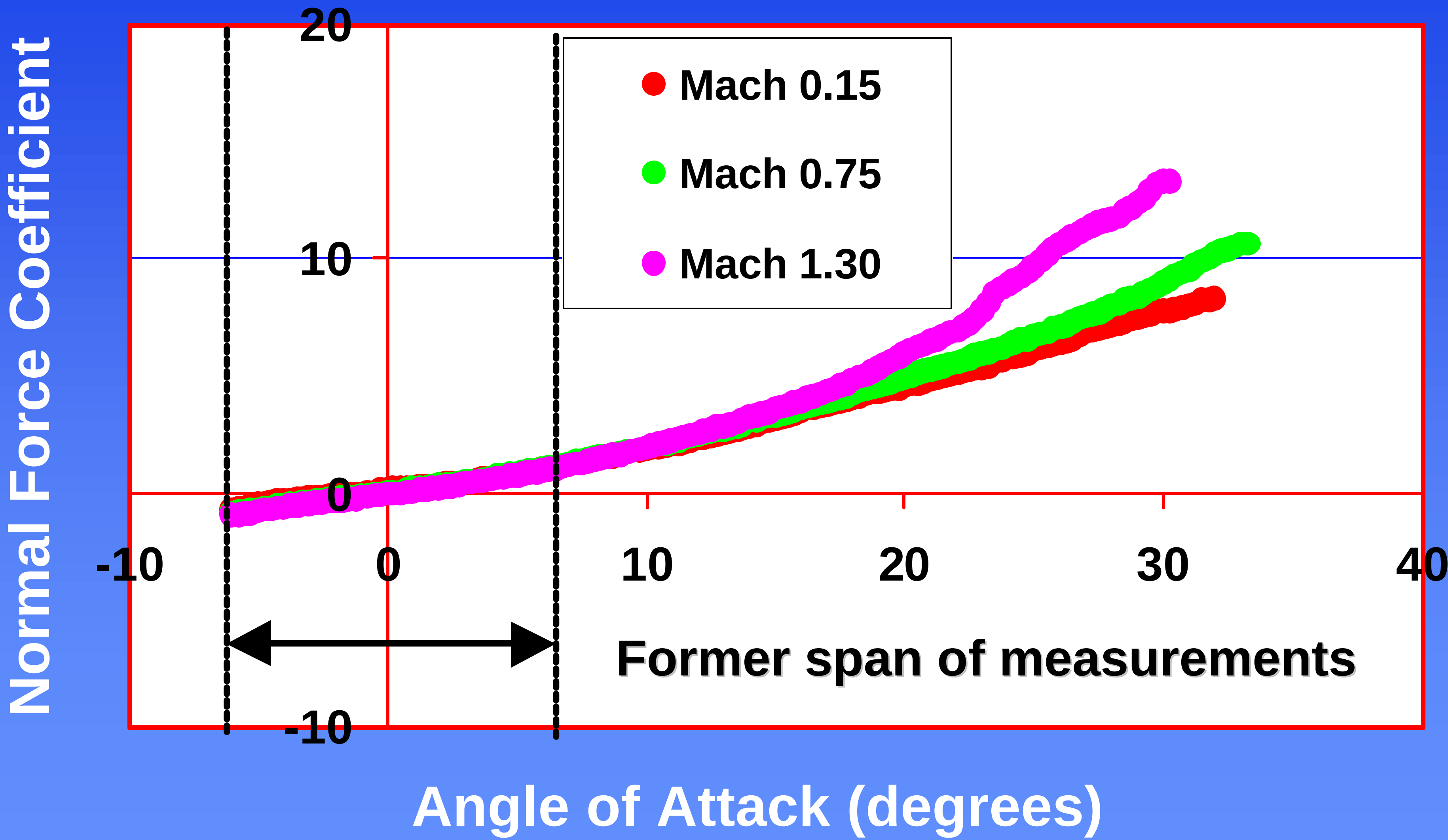




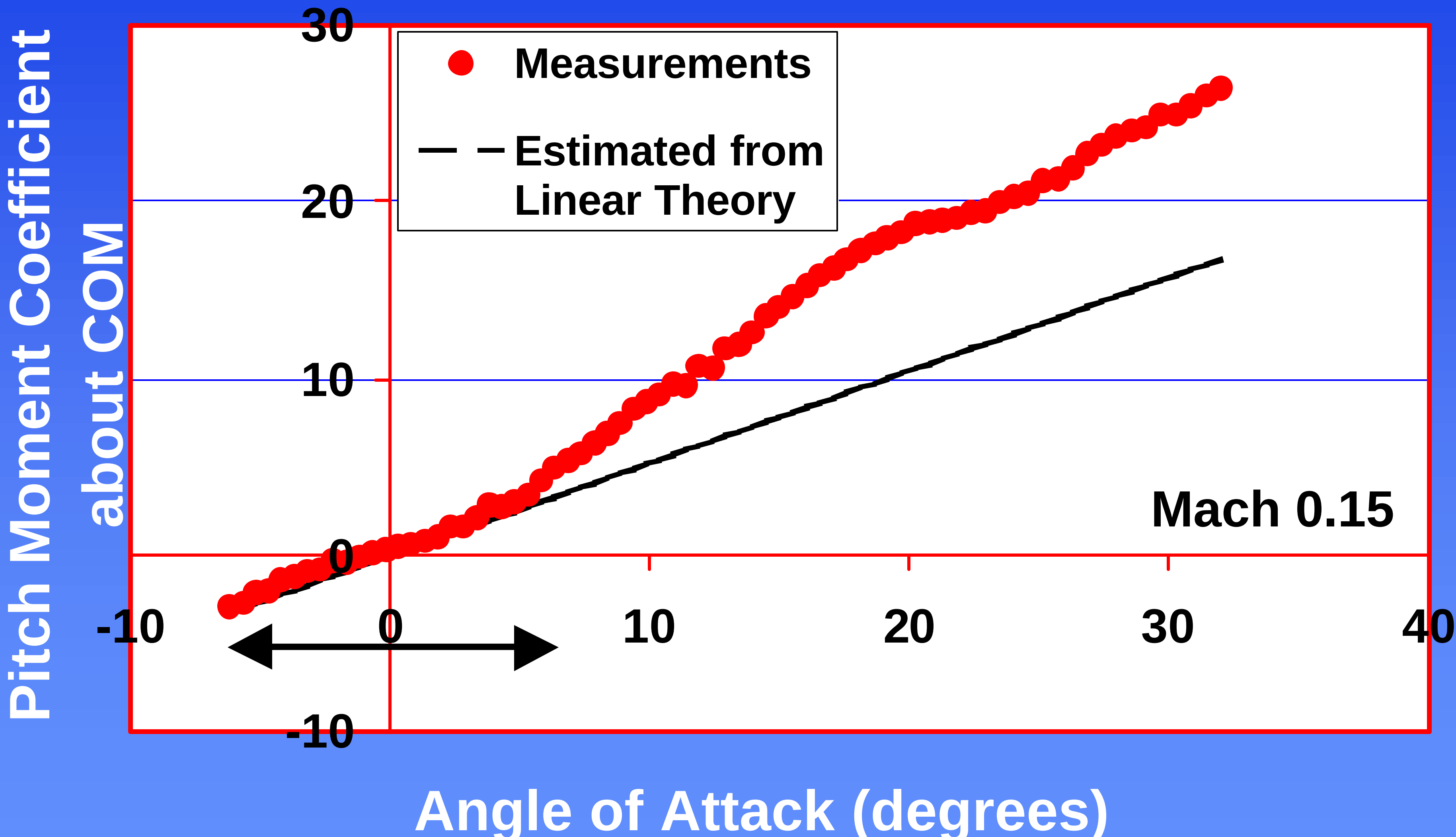
Wind tunnel tests yielded data about low speed behavior



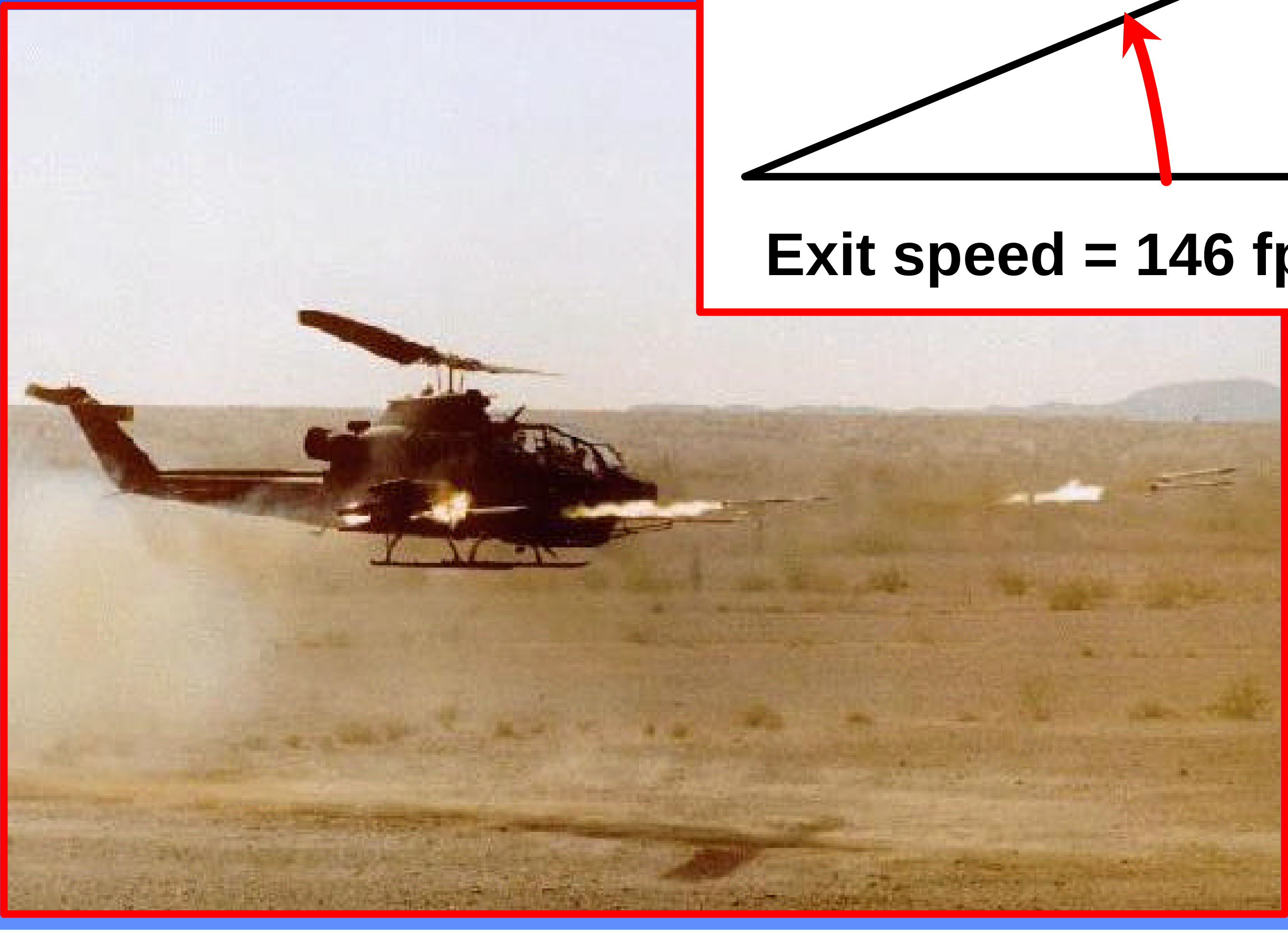
Wind tunnel tests greatly expanded knowledge of high AOA behavior

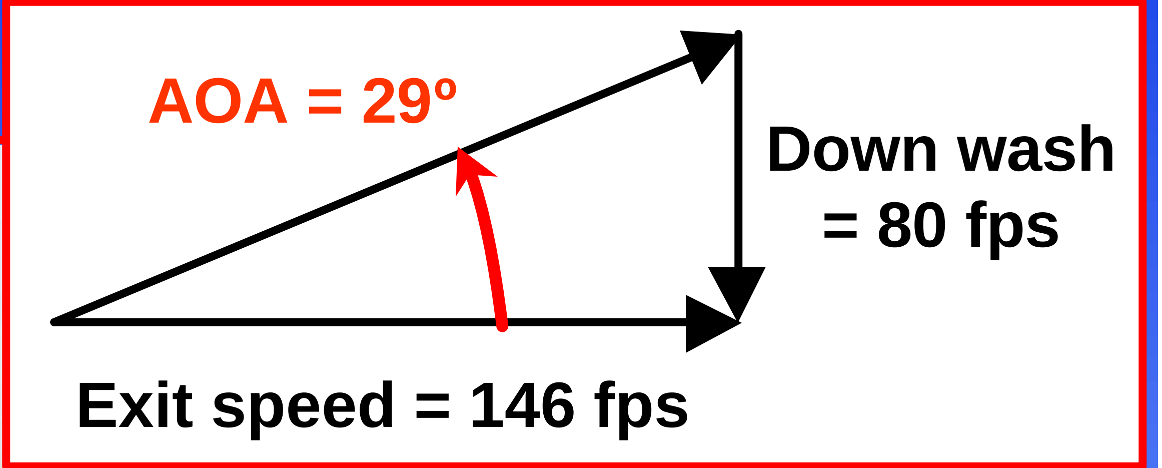


High AOA forces and moments are greater than previously estimated

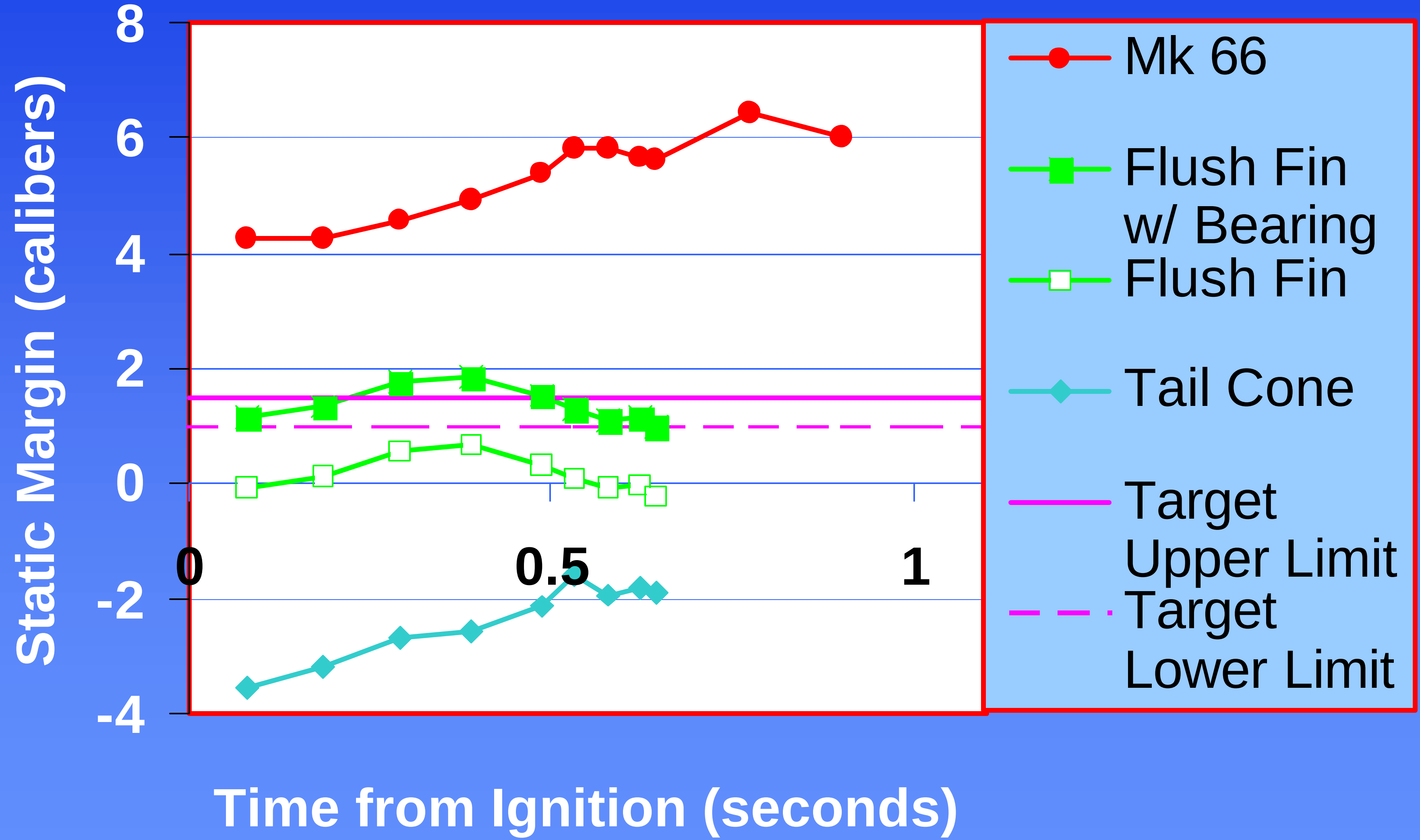


High AOA is probable during launch





Static stability varied significantly among tested designs



“Flush fin” design offers a range of potential benefits

- Lower static margin reduces response perturbations caused by rotor blade downwash.
- One-piece shell reduces cost to machine and assemble (versus the 10+ pieces with current nozzle design).
- Lower fin profile lowers loads and allows fabrication from low-cost, low-weight polymers.
- Flush fins allow quicker rocket loading without the user having to constrain spring-loaded “wrap around” fins.
- Reduced roll damping allows early spin-up to be maintained throughout flight.
- Lower static margin allows for APKWS weapon guidance at high velocities for the future generations of 2.75” rocket motors.

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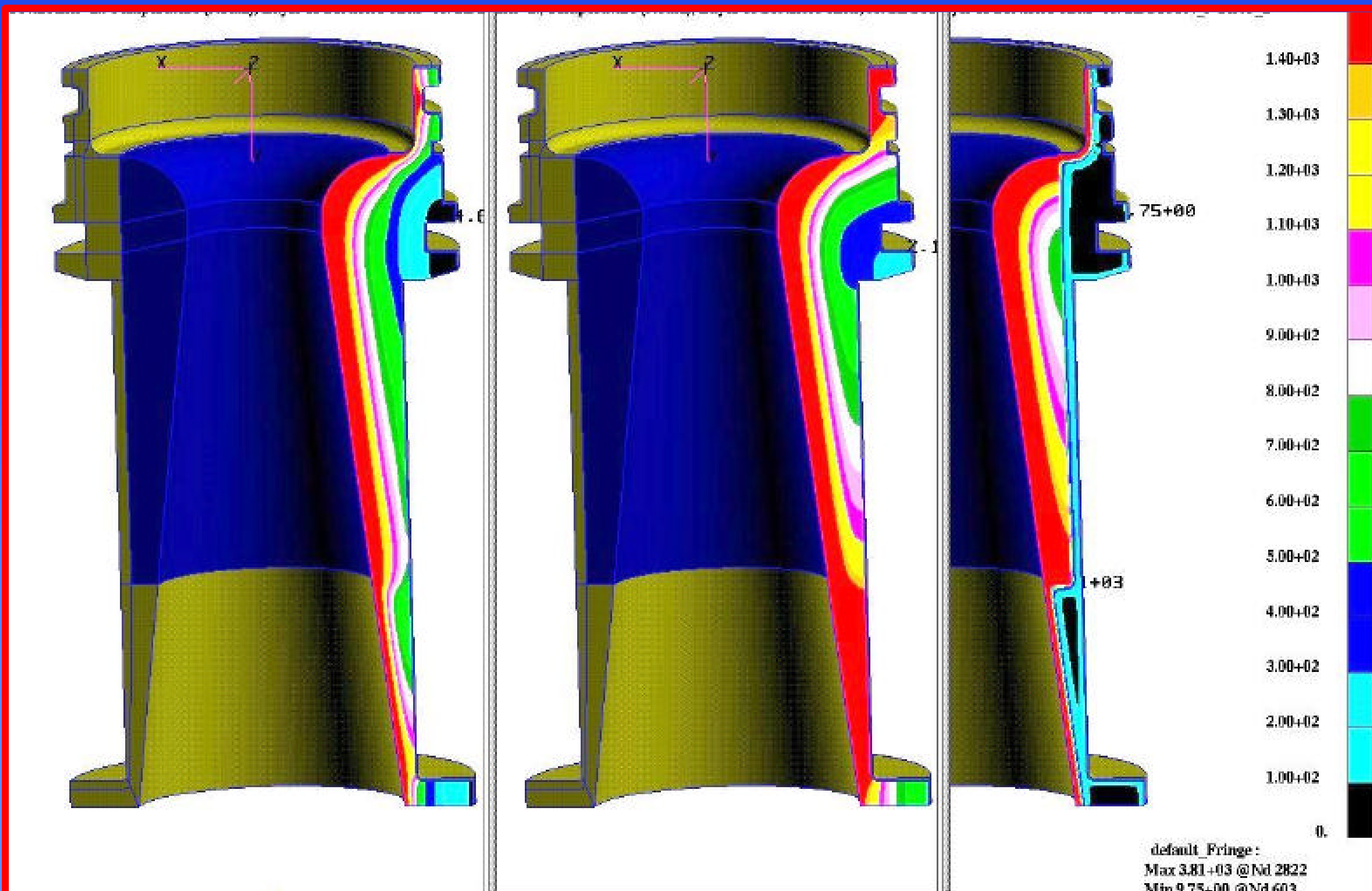
Engineering design remains to be done



Predicted temperature at 1.0 second

Actions are planned to refine the design concepts

- Engineering (thermal and structural) design of lightweight nozzle
- Verification of torque mechanism
- Demonstration of roll bearing
- Definition of mass properties
- Wind tunnel tests to finalize aerodynamic properties
- Ground–launch flight tests